

# EXPERIMENTAL, TEST AND RESEARCH BEAMLINES AT FERMILAB\*

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## Abstract

Three new external beamlines are in operation or under development at Fermilab: 1) a proposed new MTEST beamline for advanced detector work for high energy physics experiments and the ILC, 2) the Main Injector Particle Production (MIPP) beamline and 3) the MuCool Test Area (MTA) beamline. A new MTEST beamline is under design to provide secondary beams at ultra-low to high energies, from  $\sim 1$  GeV to  $\sim 90$  GeV in addition to a primary, 120 GeV proton mode of operation. It is anticipated that this last line will be installed in fall of 2006. The second line, the MIPP beamline, is a secondary production beamline capable of producing well-characterized beams of protons, pions, and kaons from 5-120 GeV/c using the 120 GeV/c proton beam from the Fermilab Main Injector. The last line is a new 400 MeV primary proton beamline derived from the 400 MeV Fermilab proton Linac which will provide for precision measurements of Linac beam parameters in addition to a high-intensity primary test beam for development and verification of muon cooling apparatus. A dual mode operation will also provide accurate dispersion-free measurements of Linac beam properties with potential for diagnostic calibration and development. Installation is planned for 2007 of this line.

## INTRODUCTION

Three new external beamlines are in operation or under development at Fermilab: 1) a proposed new MTEST beamline for advanced detector work for high energy physics experiments and the ILC, 2) the Main Injector Particle Production (MIPP) beamline. and 3) the MuCool Test Area (MTA) beamline. A new MTEST beamline is under design to provide secondary beams at ultra-low to high energies, from  $\sim 1$  GeV to  $\sim 90$  GeV in addition to a primary, 120 GeV proton mode of operation. It is anticipated that this last line will be installed in fall of 2006. The second beamline, the MIPP beamline, is a secondary production beamline capable of producing well-characterized beams of protons, pions, and kaons from 5-120 GeV/c using the 120 GeV/c proton beam from the Fermilab Main Injector. The last line is a new 400 MeV primary proton beamline derived from the 400 MeV Fermilab proton Linac which will provide for precision measurements of Linac beam parameters in addition to a high-intensity primary test beam for development and verification of muon cooling apparatus. A dual mode operation will also provide accurate dispersion-free measurements of Linac beam properties with potential for

diagnostic calibration and development. Installation is planned for 2007 of this line.

The primary beamline for both MIPP and MTEST extends for well over a thousand meters through various beam splits back to the Main Injector. Control over primary beam characteristics local to either MIPP or MTEST is established through two focusing quadrupole doublets and adjustable collimators located roughly a few hundred meters upstream of the primary target, in both cases. The primary intensity regulation is not provided by collimators (with the exception of primary-mode, 120 GeV/c proton running), but by movable electrostatic separators which split the primary proton beam slow extracted from the Main Injector into three channels, MTEST, MIPP and a primary beam absorber. Although not a fine adjustment, intensity can be controlled to these two experiments through position of the electrostatic separators by about two orders of magnitude over and above the beam delivered by the Main Injector which can also be intensity regulated over a large range. The primary line will be tuned and collimated accordingly to maintain a consistent spot size over a large range in primary intensity. The primary intensity will depend on the secondary beam energy and desired event rate.

The MTA beamline is instead intensity-controlled by changing the repetition rate ( $\leq 15$  Hz) of a fast injection magnet in combination with an electrostatic beam chopper which can vary the Linac pulse length between 2 and 50  $\mu\text{sec}$ , a change that corresponds to a per pulse intensity of  $0.06 - 1.3 \times 10^{13}$  protons..

## THE NEW MTEST BEAMLINE

The MTEST beamline has successfully supplied a secondary beam of pions, kaons, and protons from an energy of  $\sim 16$  GeV to  $\sim 100$  GeV and 120 GeV for primary protons. With a  $\sim 500$  m beamline, low energy pions do not survive and material in much of the beamline eliminates low energy hadrons and electrons. The optics is also not suited in terms of magnetic strength and power-supply regulation to support low-energy operation. The current proposal is to reduce the beamline to approximately 100 m, which, even with 30 m of Cherenkovs shortens the line by about a factor of 3 from the primary target to the start of experimental setup. That and the avoidance of air gaps and elimination of material in the beamline is predicted to generate a factor of 90 more 1 GeV pions and a factor of 90 and 25 more 4 GeV electrons and hadrons, respectively. Further, upgraded optics will be installed to control and fix acceptance, momentum spread, different operational tunes, beam divergence control at the Cherenkovs (a  $< 0.5\text{mr}$  parallel beam, for example), all with independent spot size control at the experiments. Halo and backgrounds are expected to be mitigated with the new beamline, an important issue at

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low energy. Design specifications are listed in Table 1 for the proposed beamline.

Table 1: New MTEST Beam Specifications

Energy	1 GeV $\rightarrow$ 60 or 90 GeV
Momentum Bite/resolution	$\pm 2\% \delta p/p$
Nominal spot size @exp.	$\pm 0.5''$
Beam div. @Cherenkovs	$\leq 0.3$ mr
Horz. dispersion @ exp.	1% $\delta p/p$ per inch

The optics of the new line has been optimally designed to separate the primary 120 GeV proton beam from a high energy secondary beam (up to 60-90 GeV) within the constraint of the present tunnel enclosure. Triplet quadrupole structures have been used for several reasons: 1) to enhance the separation of the primary beam from the secondary allowing a higher energy secondary, 2) to increase acceptance and equalize beam envelopes for a circular beam from the primary target, 3) to provide greater flexibility in beam properties over doublet quadrupole optics, 4) to enhance the natural dispersion of the bend dipoles at the momentum collimation, and 5) better control of beam envelopes through aperture-limited components (namely a string of 5 EPB dipoles required downstream of the momentum collimation). A final quadrupole doublet is also used to control beam divergence, spot size, and dispersion at the experiments independent of upstream operation, thus fixing beam properties and making them independent of experimental requirements. An example of two different line tunes and envelopes with corresponding divergences is given in Figure 1.

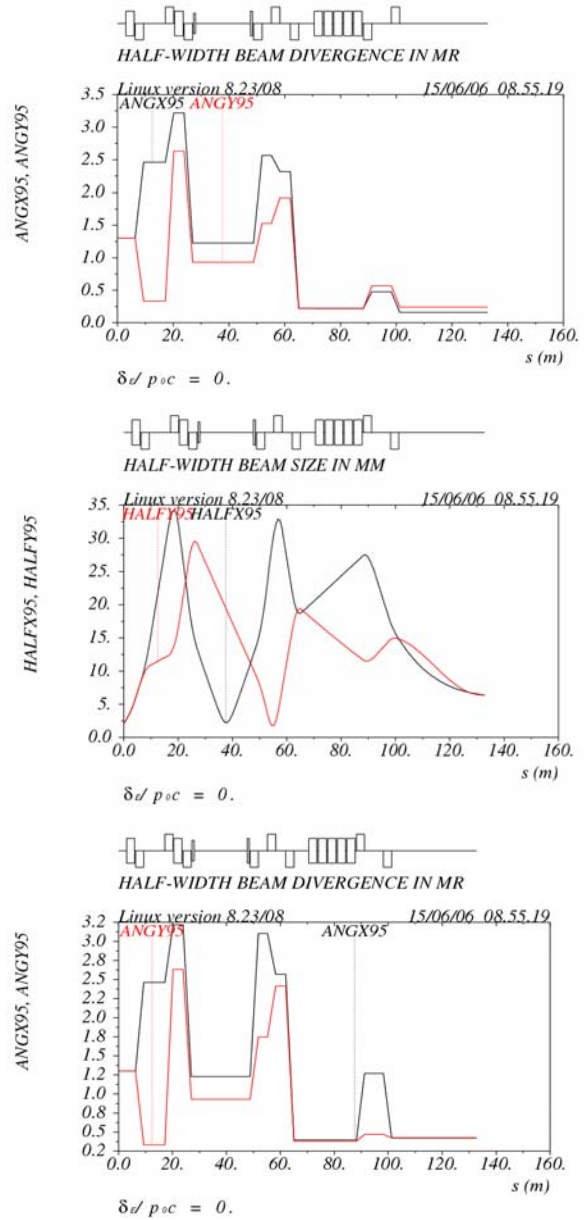
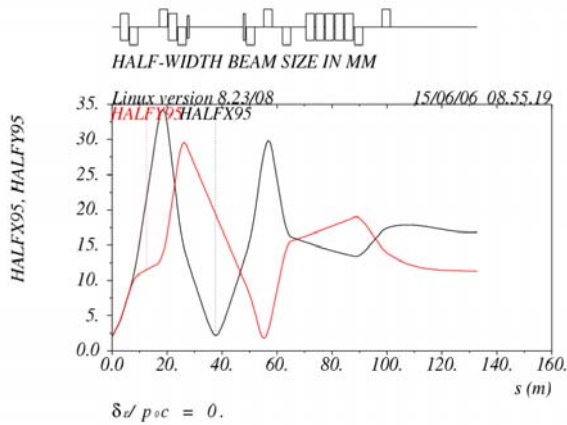


Figure 1. Plots of the  $\frac{1}{2}$ -width beam envelopes and angular divergences for two different spot sizes at the MTEST experimental area.

## THE MIPP BEAMLINE

Experiment 907 at Fermilab was conducted and may continue after an upgrade in the Meson Center beam enclosure. The purpose of this experiment is to measure cross sections for hadron production from nuclear interactions using pions, kaons and proton beams in the momentum range from 5 to 120 GeV/c. Light to heavy targets were used to study the scaling laws of hadronic fragmentation and light meson and baryon spectroscopy. Design aspects for the experiment's beamline are presented here and in more detail in an earlier reference[1]. The lattice, in particular the secondary beamline design, the primary target, and the collimation system are covered.

## MIPP Primary and Secondary Beamlines

The length available to the experiment for primary beam control and the secondary beamline totals only 128m, with 41m reserved for the threshold and ring-imaging Cerenkovs. Due to enclosure restrictions and the need for primary beamline magnets in this section (no superconducting magnets are used), the primary portion must remain at least 20 m long. Less than 100 meters is left to accommodate the necessary secondary line optics—optics appropriate for momentum selection and which also meet the beam envelope and divergence criteria for the experiment. The resulting beam optics which uses a pair of quadrupole triplets to form a momentum-dispersed image at the momentum collimator and a  $\sim 0.3$  mr (rms) divergent beam through the Cerenkovs is illustrated in Figure 2.

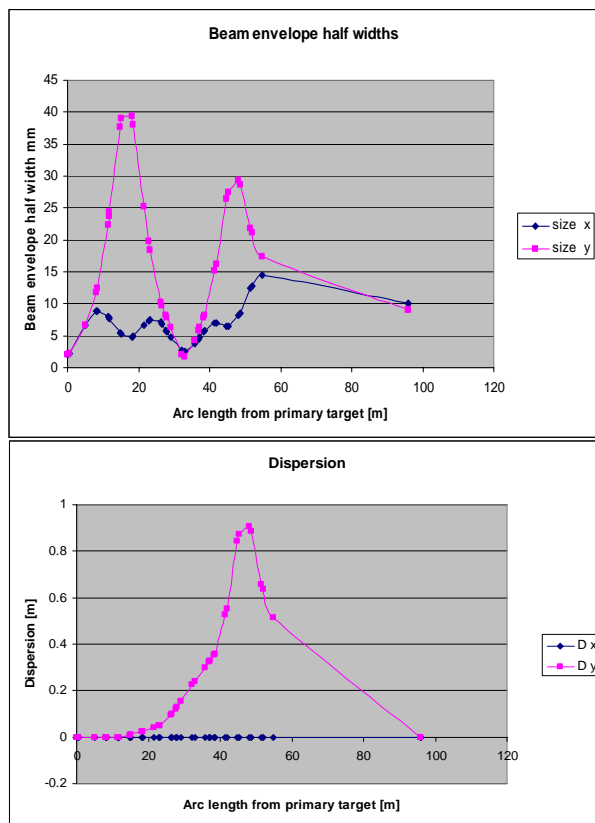


Figure 2. Plots of the  $\frac{1}{2}$ -width beam envelopes and angular divergences for two different spot sizes at the MTEST experimental area.

This beamline design was highly successful, operating from 5 GeV up to 90 GeV secondary energies and a 120 GeV primary proton mode. The beamline successfully achieved a 1" spot size at the experiment's secondary target with  $\pm 2\%$  momentum bite using a momentum collimator at the vertical focus between the two quadrupole triplets. The new MTEST beamline design was based on the successes of this line. Dispersion which

was canceled at the MIPP experiment per experimenters' request could not be revised after design due to the constrained nature of this line. (Flexible values for dispersion at the experiment was implemented in the proposed MTEST line.)

## THE MTA BEAMLINE

Civil construction has recently been completed on a new beamline and experimental facility designed to use a primary, 400-MeV  $H^-$  beam extracted directly from the Fermilab Linac[2]. The facility located just southwest of the Linac will be capable of accepting the full Linac beam intensity ( $1.6 \times 10^{13}$  protons @ 15 Hz) to within the radiological limits permitted by the current state of shielding and controls — making it one of the few such facilities in the world where a primary beam is available and a primary enclosure accessible. A low-loss beamline with specialized insertions for linac beam diagnostics has been recently been designed and incorporated in the line delivering beam to the MuCool (Muon Cooling) Test Area or MTA hall. This designed-in capability for beam measurements greatly enhances the functionality of this line making a valuable contribution to accelerator operation in addition to hosting muon cooling and other high-intensity experiments and general R&D efforts.

This beam will be used initially for cryogenic tests of liquid-hydrogen absorbers for the MUCOOL R&D program and, later, for high-power beam tests of these absorbers and other prototype muon-cooling apparatus. The emittance measurement is projected to be accurate to about 10%.

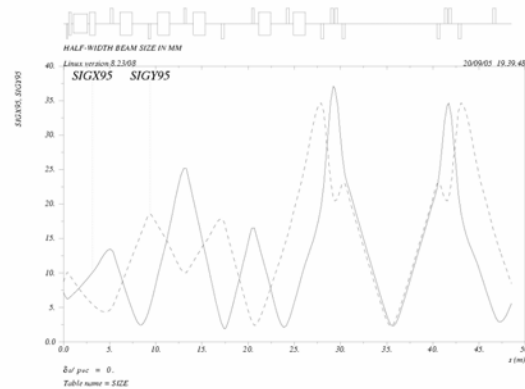


Figure 3. Beam sizes (half width, 95%) in MTA beamline show low-beta insertion for emittance measurements.

## REFERENCES

- [1] C. Johnstone, "Beamline Design for Particle Production Experiment, E907, at FNAL," PAC'03, Portland, May 2003, p. 1446.
- [2] C. Johnstone, "MuCool Test Area a Fermilab," PAC'05, Knoxville, May 2005, p. 3482.